A Decision Based Support System Based on GIS Technology

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INTRODUCTION

The continuous increase of the national expense for the healthcare services, the necessity to adjust the performance of the service of the National Healthcare System to the change of the demand of health coming from the population, and the necessity to evolve towards a logic of integration along a *"continuum of care,"* push for the reorganization of healthcare services inside the local healthcare district. This should permit:

1. The increase of the efficiency level, by means of economies of scale, know-how diffusion, the elimination of redundant resources;
2. The acquisition of competitive advantage for the network components, which are focused on specific areas and are subject to a smaller competitive pressure, due to the existence of protection mechanisms;
3. The increase of clinical effectiveness; and
4. The increase of the quality of service.

On this basis, it is possible to define the main factors to take into account for the reorganization of healthcare services inside the healthcare district: (1) the territorial distribution of the services; (2) the citizen-customer satisfaction, in terms of expectations and preferences; (3) the centralization of high complexity services as a guarantee of quality and cost sustainability; (4) the appropriateness of the healthcare services, in relationship with the local needs of health.

The study of these factors implies the analysis of a great amount of quantitative and qualitative variables, and the management of different types of data, including geographical information.

According to Hopkins (1977) and Collins et al. (2001), such a problem can be expressed as a complex localization problem, and consists of the identification of the most suitable location, according to specific priorities and to the features of the activities to be performed.

In particular, its application to the integrated healthcare network model consists of the research of the optimal location for local healthcare services.

A useful tool to support the solution of localization problems is represented by Geographical Information Systems (GISs) (Mullner, Chung, Croke, & Mensah, 2004). Such technologies are able to store, process, and represent large quantities of data, combining data management and spatial referencing capabilities. They are also able to screen the set of alternatives, and so, they can provide support when the set of location alternatives is very large (Eastman, Kyem, & Toledano, 1993). Because of this, they can be used as support tools for solving optimisation problems. This can be done by integrating optimisation models in a GIS environment (Lin & Kao, 1998). However, the growing dimension of the problem makes the integration of optimisation techniques into a GIS environment very difficult, increasing the computational complexity.

The application of *multiattribute* and *multicriteria methods* (Chan, 2001), based on heuristic techniques, can be an alternative solution. These methods cannot lead to the optimal solution, but they permit to identify "most suitable" locations, even when the complexity of the problem is high (Malczewski, 2004). They are generally based on criteria weighting techniques, such as Analytic Hierarchy Process (Saaty, 1990) and Simple Additive Weighting (Carver, 1991; Eastman et al., 1993), and their use is suggested when techno-

logical limitations do not permit to use more complex methods to calculate the optimal solution (Cromley & Hanink, 1999).

LOCALIZATION METHODOLOGY

The solution of the localization problem of a healthcare network cannot be disjointed from the analysis of all those factors influencing the perception of the health services by the patients. Such factors have both a quantitative dimension (e.g., the distance from the essential service), and a qualitative one (e.g., the perceived quality level of local healthcare services, or the chance to choose the place where to receive assistance).

With reference to this, Fortney, Rost, and Warren (2003) point out five possible dimensions for the analysis: affordability, acceptability, accomodation, availability, and accessibility. The last one tends to be extremely useful for examining the spatial interaction between healthcare services and patients. Nevertheless, the accessibility problem has to be solved, referring to the analysis of the demographic, economic, and social characteristics of the healthcare district, aimed at identifying the health problems and needs of the population (Curtis & Taket, 1996) and pointing out possible situations in which the risk to be not cured, or to be cured late, is very high (Brown, 1988).

According to Harper, Shahani, Gallagher, and Bowie (2004) the localization of the healthcare services is based on eight factors considered relevant for spatial analysis:

1. **Services and clinical speciality:** Analysis of the currently provided services, in terms both of medical, surgical, or diagnostic services, and of resources (namely, number of beds, physicians, nurses, and so on).
2. **Actual location of the healthcare centres:** Analysis of the localization in the examined area of the services with high and low specialization, aimed to identify zones in which it is necessary to locate new services or zones in which there is useless redundancy.
3. **Distribution of the population:** Analysis of the potential patients who reside in the area of the existing healthcare centres, also using social and economic data.
4. **Demand of health:** Analysis of the health demand referred to different healthcare services.
5. **Waiting times for the access to the cares:** It is important to find the trade-off between resources and system performance, in terms of waiting time for the access to cares.
6. **Routes:** It is necessary to assure the accessibility of all patients to given centres.
7. **Estimation of the minimal area:** It is opportune to verify if the potential demand of healthcare services, which characterizes a fixed area, is high enough to justify the location of a new healthcare centre.
8. **Patient preferences:** This concept can be expressed by means of a set of qualitative variables: for instance, the reputation of the healthcare centre, the presence of renowned experts (the patient is usually disposed to wait a long time for a high quality of service), and the perceived quality of services.

Aiming at finding a solution to this complex localization problem—with the specific objective to identify the most suitable location for a new healthcare service in the local healthcare district—a GIS-based methodology has been developed and proposed, adopting the following steps (Digregorio, 2006):

1. Collection of data related to the healthcare district area;
2. Definition of the criteria which affect the choice of the location for a new healthcare service. It is possible to identify two main categories:
   a. the admissibility criteria—the criteria which are considered essentials for eligibility;
   b. the optimality criteria—the criteria which are used for identifying the most suitable location between those who satisfy all admissibility criteria.

   At this step, the analysis considers only basic healthcare services (medicine), such as cardiology, paediatrics, audiology, geriatrics, neurology;
3. Identification of the admissible solutions—the solutions that satisfy the admissibility criteria;
4. Assignation of weights to optimality criteria and the application of the spatial analysis models for the search of the most suitable location (optimal solution)—that is, the admissible location